

and for receiver data collected using the insulated loop source 6 and the earth's natural background magnetotelluric source when the other sources are turned off. Preferably, joint inversions of receiver data collected using any combination of the grounded source (4 and 5 in FIG. 1, 11 and 12 in FIG. 2), insulated source 6, and magnetotelluric source are also performed.

Please amend claims 1, 2, 3, 4, 6, 8, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, and 21 per the replacement pages provided. Please delete claim 9. In addition, please add new claims 22-34. A marked-up version of the claims is enclosed.

REMARKS

The specification has been amended to correct the reference to the earlier filed, copending provisional application. In addition, typographical errors have been corrected without adding new matter.

Claims 1-21 are pending in the above-identified application. Examiner rejected claims 1 and 17, and objected to claims 2-16 and 18-21.

Claims 1 and 17 have been amended to overcome Examiner's rejection. As amended, claims 1 and 17 are in proper form and Applicant respectfully requests that Examiner's rejection be withdrawn.

Claims 1, 2, 3, 4, 6, 8, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, and 21 have been amended for clarification and to correct references to base claims. No new matter has been added. Applicant respectfully requests objections to these claims to be withdrawn.

New claims 22-34 have been added. These claims allow Applicant to more fully claim the subject matter of his invention. Applicant respectfully requests these claims be allowed.

In summary, each of the claims of the application is limited to Applicant's inventive subject matter and are patentably distinct from all known prior art. Therefore, Applicant respectfully requests allowance of all pending claims.

If there are any questions concerning the foregoing, please contact the undersigned at the number provided below.

Respectfully submitted,

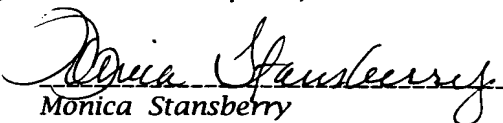
Date: May 3, 2002


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I claim:



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1. **(once amended)** A method for surface estimation of ~~reservoir~~
~~properties~~ a resistivity depth image of a subsurface geologic formation,
comprising the steps of:

determining the location of and at least one average earth resistivity
~~above, below, and horizontally adjacent to~~ for the vicinity of the subsurface
geologic formation using geological and geophysical data ~~from~~ in the vicinity of
the subsurface geologic formation;

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determining dimensions and probing frequency for an electromagnetic
source to substantially maximize transmitted vertical and horizontal electric
currents at the subsurface geologic formation using the location and the at
least one average earth resistivity;

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activating the electromagnetic source at or near the surface of the
earth, approximately centered above the subsurface geologic formation;

measuring a plurality of components of electromagnetic response with
a receiver array;

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determining one or more geometrical and electrical parameter
constraints, using the geological and geophysical data; and

processing the electromagnetic response using the geometrical and
electrical parameter constraints to produce the inverted vertical and horizontal
resistivity depth images.

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2. **(once amended)** The method of claim 1, further comprising the step
of:

combining the ~~inverted~~ resistivity depth images with the geological and
geophysical data to estimate one or more ~~the reservoir~~ properties of the
subsurface geological formation.

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3. **(once amended)** The method of claim 12, wherein the step of
determining dimensions and probing frequency is accomplished by
numerically solving the uninsulated buried low-frequency electromagnetic

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antenna problem ~~for the vertical electrical current at the subsurface geologic formation.~~

4. (once amended) The method of claim 12, wherein the
5 electromagnetic source comprises;

two continuously grounded circular electrodes positioned ~~at or within the near surface~~ in concentric circles.

5. (once amended) The method of claim 4, wherein each circular
10 electrode comprises one or more electrically uninsulated conductors.

6. (once amended) The method of claim 42, further comprising:
a third circular electrode positioned ~~at or within the near surface and~~
concentric with the two circular electrodes.

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7. (once amended) The method of claim 6, wherein the third circular
electrode comprises one or more electrically insulated conductors.

8. (once amended) The method of claim 12, wherein the
20 electromagnetic source comprises;

six or more grounded linear radial electrodes of equal lengths
placed along radii separated by equal angles, whose radial projections
intersect at a common central point; ~~and~~

25 ~~continuously grounded linear terminating electrodes connected~~
~~perpendicularly at each end of the grounded electrodes.~~

~~9. The method of claim 8, wherein the length of the terminating electrodes~~
~~is less than or equal to one tenth of the length of the radial electrodes.~~

30 10. (once amended) The method of claim 8, wherein the radial
electrodes are continuously grounded along their entire length..

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11. (once amended) The method of claim 8, wherein the radial electrodes are continuously grounded only within a distance less than one half of the length of the radial electrode, from each end.

5 12. (once amended) The method of claim 12, wherein the subsurface geologic formation is located onshore ~~and wherein the plurality of components of electromagnetic response comprise:~~
~~two orthogonal horizontal electric fields;~~
~~two orthogonal horizontal magnetic fields; and~~
10 ~~a vertical magnetic field.~~

13. (once amended) The method of claim 12, wherein the subsurface geologic formation is located offshore and the surface of the earth is the seafloor ~~wherein the plurality of components of electromagnetic response~~
15 ~~comprise:~~
~~two orthogonal horizontal electric fields;~~
~~two orthogonal horizontal magnetic fields;~~
~~a vertical magnetic field; and~~
~~a vertical electric field.~~

20 14. (once amended) The method of claim 12, wherein the receiver array is positioned on a grid.

15. (once amended) The method of claim 12, wherein the receiver array
25 is positioned as a linear array.

16. (once amended) The method of claim 12, wherein the receiver array is positioned as a swath array.

30 17. (once amended) The method of claim 1, wherein the step of processing the electromagnetic response further comprises ~~the step of:~~

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verifying the at least one average earth resistivities ~~is above, below, and horizontally adjacent to the subsurface geologic formation,~~ using the plurality of components of electromagnetic response measured with the receiver array.

5 18. **(once amended)** The method of claim 12, wherein the step of processing the electromagnetic response further comprises ~~the step of:~~
applying 3-D wave-equation data processing to the electromagnetic response.

10 19. **(once amended)** The method of claim 12, wherein the data step of processing the electromagnetic response further comprises ~~includes~~ data noise suppression, source deconvolution, and model-guided inversion.

15 20. **(once amended)** The method of claim 97, wherein the steps of activating the electromagnetic source and measuring the plurality of components of the electromagnetic response further comprises ~~the steps of:~~

measuring a first electromagnetic response without activating the electromagnetic source;

20 measuring a second electromagnetic response while activating only the third circular ~~insulated~~ electrode; and

measuring a third electromagnetic response while activating only the two continuously grounded circular ~~uninsulated~~ electrodes.

25 21. **(once amended)** The method of claim 20, wherein the step of ~~applying data processing~~ the electromagnetic response further comprises ~~the steps of:~~

merging the first and second electromagnetic responses to produce a fourth electromagnetic response;

~~inverting the first electromagnetic response;~~

30 ~~inverting the second electromagnetic response;~~

~~inverting the third electromagnetic response;~~

inverting the fourth electromagnetic response; and

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inverting jointly the third and fourth electromagnetic responses.

22. (new) The method of claim 21, wherein the step of processing the electromagnetic response further comprises at least one step chosen from:

- 5 inverting the first electromagnetic response;
- Inverting the second electromagnetic response; and
- Inverting the third electromagnetic response.

23. (new) The method of claim 1, wherein the resistivity depth image comprises at least one depth image component chosen from an inverted vertical resistivity depth image, an inverted horizontal resistivity depth image and an inverted three-dimensional resistivity depth image.

24. (new) The method of claim 1, wherein the dimensions and probing frequency are verified using iterated 3-D modeling.

25. (new) The method of claim 8, further comprising continuously grounded linear terminating electrodes connected substantially orthogonally at each end of the grounded radial electrodes.

26. (new) The method of claim 25, wherein the length of the terminating electrodes is less than or equal to one tenth of the length of the radial electrodes.

27. (new) The method of claim 1, wherein the electromagnetic source comprises a sub-optimal configuration.

28. (new) The method of claim 12, wherein the plurality of components of electromagnetic response comprise:

- 30 two orthogonal horizontal electric fields;
- two orthogonal horizontal magnetic fields; and
- a vertical magnetic field.

29. (new) The method of claim 28, wherein the plurality of components of electromagnetic response further comprises a vertical electric field.

5 30. (new) The method of claim 13, wherein the plurality of components of electromagnetic response comprise:

two orthogonal horizontal electric fields;

two orthogonal horizontal magnetic fields;

and a vertical electric field.

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31. (new) The method of claim 30, wherein the plurality of components of electromagnetic response further comprise a vertical magnetic field.

15 32. (new) A method for surface estimation of an inverted resistivity depth image of a subsurface geologic formation, comprising the steps of:

determining the location of and average earth resistivity above, below, and horizontally adjacent to the subsurface geologic formation using geological and geophysical data from the vicinity of the subsurface geologic formation;

20 determining dimensions and probing frequency for an electromagnetic source to substantially maximize transmitted vertical and horizontal electric currents at the subsurface geologic formation using the location and the at least one average earth resistivity, said source comprising six or more grounded linear radial electrodes of equal lengths placed along radii separated by equal angles whose radial projections intersect at a common central point, continuously grounded linear terminating electrodes connected
 25 substantially orthogonally at each end of the grounded radial electrodes;

activating the electromagnetic source at or near the surface of the earth, approximately centered above the subsurface geologic formation;

30 measuring a plurality of components of electromagnetic response with a receiver array;

determining one or more geometrical and electrical parameter constraints, using the geological and geophysical data; and

5 processing the electromagnetic response using the geometrical and electrical parameter constraints to produce the inverted resistivity depth image.

33. (new) A method for surface estimation of one or more properties of a subsurface geologic formation, comprising the steps of:

10 determining the location of and at least one average earth resistivity for the vicinity of the subsurface geologic formation using geological and geophysical data from the vicinity of the subsurface geologic formation;

15 determining dimensions and probing frequency for an electromagnetic source to substantially maximize transmitted vertical and horizontal electric currents at the subsurface geologic formation using the location and the at least one average earth resistivity, said source comprising six or more grounded linear radial electrodes of equal lengths placed along radii separated by equal angles whose radial projections intersect at a common central point;

20 activating the electromagnetic source at or near the surface of the earth, approximately centered above the subsurface geologic formation;

measuring a plurality of components of electromagnetic response with a receiver array;

25 determining one or more geometrical and electrical parameter constraints, using the geological and geophysical data;

processing the electromagnetic response using the geometrical and electrical parameter constraints to produce one or more inverted resistivity depth images of the subsurface geologic formation; and

30 combining the inverted resistivity depth images with the geological and geophysical data to estimate the properties.

34. (new) A method for surface estimation of one or more properties of a subsurface geologic formation, comprising the steps of:

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- determining the location of and at least one average earth resistivity for the vicinity of the subsurface geologic formation;
- determining dimensions and probing frequency for an electromagnetic source to substantially maximize transmitted vertical electric currents at the
- 5 subsurface geologic formation using the location and the at least one average earth resistivity;
- activating the electromagnetic source at or near the surface of the earth, approximately centered above the subsurface geologic formation;
- measuring at least a vertical electromagnetic response with a receiver
- 10 array;
- determining one or more geometrical and electrical parameter constraints, using geological and geophysical data from the vicinity of the subsurface geologic formation;
- processing the electromagnetic response using the geometrical and
- 15 electrical parameter constraints to estimate the one or more properties.

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